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Discovery and Elimination of Dioxins from a Carbon Reactivation Process

Cincinnati Water Works, OH

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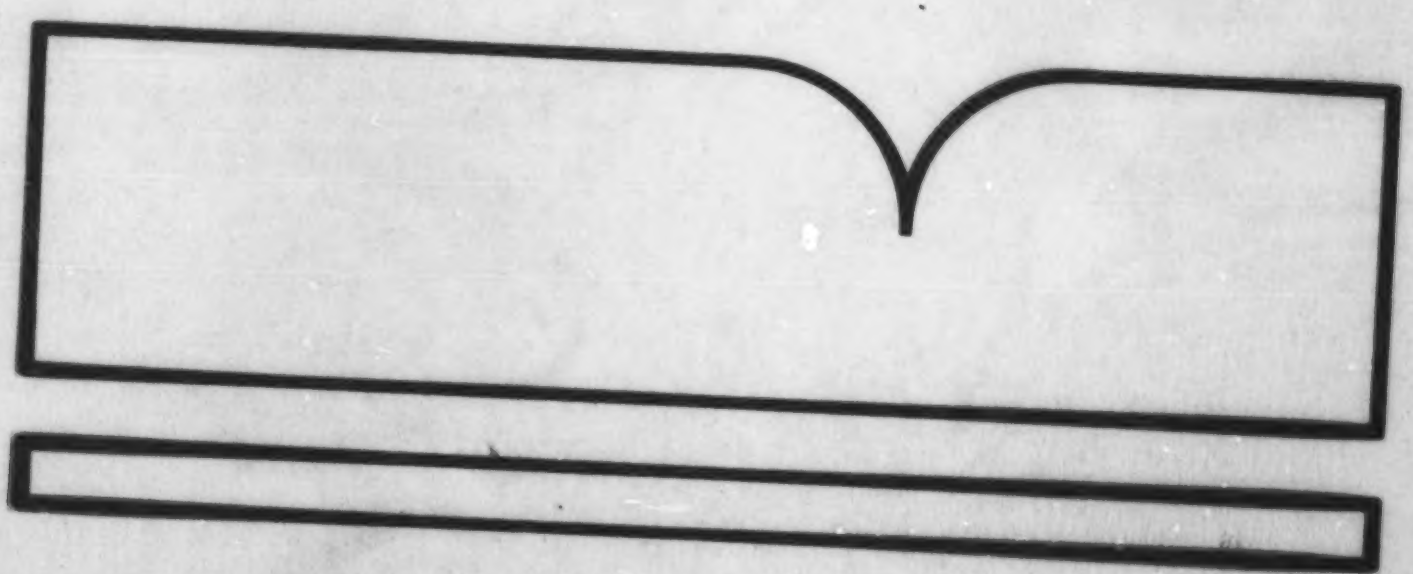
1985



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16. ABSTRACT

In a project done to ensure an environmentally acceptable granular activated carbon (GAC) adsorption and reactivation system--to be sure that chlorinated dibenzo-p-dioxins (CDD's) and chlorinated dibenzo furans (CDF's) and combustion would not present problems--results from a GAC system receiving chlorinated water were compared with those receiving unchlorinated water. The studies described here are for exhausting GAC in a post-filtration carbon contactor and reactivating GAC in a fluid-bed reactivation system. Lower stack emissions of CDD's and CDF's are produced by reactiving GAC that had received unchlorinated water.

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DISCOVERY AND ELIMINATION OF DIOXINS FROM A CARBON REACTIVATION PROCESS

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A completed ccoperative research project between the United States Environmental Protection Agency (USEPA) and Cincinnati Water Works (CWW) provided much needed data on large scale granular activated carbon (GAC) adsorption and subsequent on-site reactivation(1). The study, which was completed in 1981, convinced City of Cincinnati Water Works officials that GAC could provide an additional cost effective barrier between the industrial Ohio River water source and the consumers of Cincinnati drinking water. To further insure that such a system would be an environmentally acceptable neighbor, subsequent studies of the reactivation system were conducted. Although unrequired by any regulations, City officials wanted to be sure that speculations about dioxins (CDD's), furans (CDF's) and combustion would not present any problem in our future GAC activities.

Adsorption and reactivation testing results for GAC that was exposed to chlorinated water were collected for comparison to GAC that was subsequently exposed to unchlorinated water and then reactivated. The broad objective was to investigate a state-of-the-art afterburner design and evaluate whether or not the system is environmentally compatible. More specific objectives include:

1. Evaluation of adsorption and reactivation results for a GAC system receiving chlorinated water and a GAC system receiving unchlorinated water.

2. Evaluation of the performance of a regular and a high temperature afterburner for destruction of organics during carbon reactivation.

This article describes the results of these studies for exhausting GAC in a post filtration carbon contactor and reactivating GAC in a fluid bed reactivation system.

Facility Description

The study was conducted at the California plant of the CWW in Cincinnati, Ohio. The normal water treatment process at the 10.3 cu m/sec (235 MGD) California plant consists of primary settling, offstream storage reservoirs, secondary settling, sand filtration and disinfection (Figure 1). Primary sedimentation is achieved using a 7.7 cu m/sec (175 MGD) facility equipped with plate settlers to separate solids and continuously return them to the Ohio River. This facility is responsible for the bulk of the turbidity removed. Along with secondary settling, the sed[illegible]ntation system results in delivery of low turbidity water to the sand filters. Also, the storage provided by the two reservoirs is

very useful during known spill conditions that frequently occur on river systems. Facilities are available to apply chlorine, aluminum sulfate and polymer to the raw water. Powdered activated carbon can also be added after primary settling, before water is delivered to the reservoirs. The plant also has facilities for feeding chlorine, ferric sulfate, lime, soda ash and powdered activated carbon between the reservoirs and secondary settling basins. Also, chlorine can be added between the secondary settling basins and sand filters as well as between the sand filters and clearwells.

Figure 1 also shows the flow process used to exhaust and reactivate GAC. Sequential studies were conducted to test whether dioxins are a factor to consider during carbon reactivation. Phase 1 involved exhausting GAC with chlorinated water from the conventional plant process and reactivating the GAC while testing for dioxins. Phase 2 was conducted with unchlorinated water entering the GAC, which is our intended full scale mode of operation. Modifications to the reactivation system and full scale plant were made by CWW and Malcolm Pirnie to allow conduct of phase 2. The phase 2 operation was designed to evaluate a high temperature afterburner that was considered a prudent investment for a GAC system on an industrial waterway.

Adsorption

Approximately 42,000 pounds of virgin carbon were exposed in each phase of operation. Metal, post filtration, adsorption contactors, designed to treat 0.04 cu m/sec (1 MGD) at a hydraulic loading rate of about 7 gpm/ft^2 and an empty bed contact time of about 15 minutes, were used during phase 1 and 2 studies. The contactors have an inside diameter of about 11 feet and contained 15 feet of 12 x 40 mesh GAC(2,3).

Total organic carbon (TOC), total organic halogen (TOX) and trihalomethane (THM) were monitored for comparison of our present conventional system without GAC to the planned future system with GAC. Simulation of travel time from the treatment plant was used to estimate the concentrations that would be received at the consumer's tap located three days from the treatment plant. Samples taken were stored with equivalent chlorine concentrations under ambient conditions for three days(4). Then samples were treated similar to those taken at distribution system sample taps. These techniques are especially useful for THM and TOX whose concentrations vary with travel time from the treatment processes based on time, temperature, pH and free chlorine residual(5). Comparison of adsorption results with and without GAC prechlorination were of particular interest, even though the phases were conducted sequentially.

Reactivation

Figure 2 is a schematic of the reactivation system that also shows sample locations for the tests conducted in phase 1. During four separate four-hour runs, samples were taken from the spent carbon feed, cyclone catch, particulate and gaseous stack emission, scrubber water discharge and the quench water discharge from the fluid bed reactivation system. The phase 1 reactivation system conditions are shown in Table 1. The fluid bed processed spent, dewatered GAC at a 585 lb/hr rate during all test runs. The temperatures shown are an average of the conditions present during the four tests performed during phase 1. The incineration zone temperature was about 1450°F with 2% excess oxygen present to support complete combustion of organics. The incineration section of the fluid bed reactivator is an afterburner. However, the various zones are not physically separated and were designed for temperatures in the range of those noted on Table 1. Throughout this paper, the mention of an afterburner is meant to describe the physically separate unit as shown in Figure 3. The total tetrachlorodibenzo-p-dioxins (TCDD's), total tetrachlorodibenzo furans (TCDF's) and their 2,3,7,8 (2,3,7,8-TCDD or 2,3,7,8-TCDF) homologues were the primary analyses conducted during phase 1 tests. The results, although considered environmentally acceptable, caused CWW officials to initiate action for further tests of the occurrence of chlorinated dibenzo-p-dioxins (CDD's) and chlorinated dibenzo furans (CDF's).

Figure 3 is a schematic of the reactivation system that shows sample locations for the tests conducted in phase 2. The primary modification was the addition of a physically separate high temperature afterburner that received the fluid bed system off gases and the fines from the mechanical cyclone collector. These fines were pulverized to less than 40 microns and blown into the high temperature afterburner for combustion along with product gases. The afterburner was designed to provide a 2-second contact time with gases and particulates at a 2400°F temperature during normal operation. A recuperator (heat exchanger) was included to provide preheated air to the afterburner inlet. The various process streams were sampled at least once during the test sequences conducted. Table 1 also shows the reactivation system conditions for the most comprehensive reactivator tests conducted during phase 2.

Discussion of Results

Figure 4 shows that the TOC concentrations of the conventionally treated finished water delivered to the consumer's tap was similar in phase 1 and phase 2. More important is the consistently better quality water which would have been received by consumers of GAC treated water. Also, there appears to be no difference between the TOC concentrations delivered from the GAC during phase 1 (prechlorination) and phase 2 (without prechlorination).

Figure 5 likewise shows that the THM's at the consumer's tap were similar for phase 1 and phase 2 conventional treatment. Also, the GAC treated water was of much better quality (25 ug/L) for about 75 days. Concentrations less than 100 ug/L were achieved for about 100 days during phase 1 and surprisingly, during phase 2, less than 50 ug/L was achieved for over 200 days. Phase 1 included prechlorination whereas phase 2 did not. Thus, the GAC of phase 1 received a mixture of organics including THM precursors, THM's and chlorinated organics resulting from chlorine as well as those present in the raw water. Conversely, phase 2 GAC received lesser amounts of chlorinated organics because prechlorination was not used. Several reasons are being considered, but await more comprehensive data investigation before presentation. Obviously, the sequential conduct of the phases will make any explanations only tentative in nature.

Figure 6 shows that the TOX concentration leaving the plant after GAC treatment during phase 2 was lower than that of the conventional treatment system. Approximately 30% of the organic halogens in the conventional treatment effluent were accounted for by the THM's expressed as chloride. The GAC effluent only had about 20% of the organic halogen

concentration accounted for by THM's. Phase 2 data, shown on Figure 7, was collected to show the effect of 3-day travel time on TOX concentration in the distribution system. About the same percentage of TOX was accounted for by the THM's as mentioned above. As previously seen with other organics, GAC treatment provided a better water quality than conventional treatment. Phase 1 did not include effluent TOX analyses.

These data are not surprising, but simply confirm the studies of many investigators(1, 2, 6-11). Our previous studies have reported comprehensive organic removal results during a cooperative research grant between the USEPA and CWW(1).

The major new data collected during phase 1 and phase 2 were from the tests performed at various sampling locations in the reactivation systems shown in Figures 2 and 3. Table 2 shows the locations sampled during each phase. Restrictions on the amount of analytical work available required omitting the quench water location during phase 2. Additional sample locations during phase 2 included the reactivated GAC at the exit of the reactivator before water quenching and various locations within the high temperature afterburner system.

Chlorination Effects

Tables 3 through 5 contain data comparing test results obtained during reactivation of GAC that received chlorinated water (phase 1) with GAC that received unchlorinated water (phase 2). Reactivation conditions were similar during each phase of operation. The high temperature afterburner was not operated during collection of the data shown on Tables 3-5.

Table 3 data indicate that the GAC system operated without prechlorination results in a carbon loading that appears to minimize the presence of TCDD's found in any of the process streams sampled during reactivation. During phase 1, the highest TCDD concentrations were found on the particulate matter removed from the dryer off gases by the mechanical cyclone (cyclone catch). The 2,3,7,8-TCDD's were detected between 0.01 to 0.20 parts per trillion (ppt) in all four of the stack particulate samples. Phase 2 testing showed that no 2,3,7,8-TCDD and little total TCDD's were present in the cyclone catch when GAC that had received unchlorinated water was tested.

Table 4 shows similar results for TCDF data. For example, all TCDF concentrations for phase 2 were below 0.8 parts per billion (ppb) as contrasted to the 3.3 concentration found in the phase 1 results. The cyclone catch and stack emissions were where TCDD's were most frequently found. Table 5 shows that less organic halogens were adsorbed on the spent GAC operated without prechlorination, as expected. Also, the TOX adsorbed on reactivated carbon was similar to the TOX adsorbed on the virgin carbon.

The presence of prechlorination caused about a 65% increase in organic halogens on the spent carbon. The specific chlorinated compounds that constitute the TOX adsorbed on the GAC is not known. Snoeyinck, et al, (12) have reported the presence of various chlorinated organics in research regarding the effects of chlorinated water and carbon adsorbates. The influent water to carbon during phase 1 most likely had TOX concentrations of about 120 ug/L. Generally, about one third of the finished water TOX is accounted for by the chlorinated

THM's. Thus, two thirds of the TOX is caused by other chlorinated organics formed from chlorination at the treatment plant. These substances, along with THM's were adsorbed by the GAC. The authors speculated that polychlorophenols or some other chlorinated organics may have been adsorbed on the GAC and served as precursors for dioxin formation during reactivation. Thus, phase 2 was conducted to be sure that our planned full scale postchlorination mode for GAC would be without problems. The remaining discussions will deal with phase 2 results of reactivation testing performed with GAC receiving unchlorinated water. The effects of the use of a high temperature afterburner was the major focus of this phase.

Effects of Afterburner

Table 6 shows the TCDD and TCDF levels found during phase 2 testing with and without the high temperature afterburner operating. This table includes results of the tests for natural gas and fuel oil without GAC feed. All of the other results are for tests with GAC feed and natural gas as the fuel. The GAC feed rate was 585 lbs/hour. Tests 2 and 6 were performed without the high temperature afterburner in operation. However the unit does provide for incineration of particulates and gases in the incineration zone between the lower reactivation zone and the upper drying zone. As previously mentioned this is essentially an afterburner section but all references to afterburner in our work means the separate high temperature afterburner as shown in Figure 3. Tests 3, 4 and 5 were performed with the high temperature afterburner operating.

No 2,3,7,8-TCDD's were found during phase 2 testing. Also virtually no total TCDD's were detected in any of the stack test results. High temperature afterburner effects could not be determined because the TCDD results were about the same either with or without the afterburner. The TCDF data show they were present more consistently than TCDD's. Little 2,3,7,8-TCDF was present in any of the tests and was only found in the gas phase of the samples. There were other TCDF's present, as can be seen by the total TCDF column. The averages of the TCDF data show that the afterburner reduced effluent concentrations. No conclusive explanation can be presented for the fact that no TCDF's were ever detected in the particulate phase of the tests conducted during GAC reactivation. Also, no explanation is offered at this time for the presence of TCDF's in the natural gas and fuel oil runs. Additonal data would be required to provide explanations. However, the low concentrations found would not support the costs involved for further refinements.

Table 7 shows no CDD homologues below the heptachlorodibenzo-p-dioxin (hepta-CDD's) were present in the spent GAC, reactivated GAC or scrubber water sampled during phase 2. The presence of the octa-CDD has been reported to be present during many combustion processes and the USEPA appears to place little significance on any homologues of CDD's above the penta's. This can be seen by the relative potency factors used in comparing various homologues to 2,3,7,8-TCDD (13). Table 8 shows that no CDF's were detected in the reactivated GAC or scrubber water analyzed during the testing performed. Only the tetra and hepta homologues of the CDF's were detected on the spent GAC. Here again, the USEPA chlorinated dioxin workgroup (CDWG) appears to have evaluated the relative potency of all of the CDF homologues as considerably less than that of the penta CDD. Thus the tetra-CDF is

creased the levels of dioxins detected during GAC reactivation. However, even with prechlorination, the reactivation system stack emissions are well below any credible risks. Postchlorinating water after GAC treatment even further reduces any risk potential by reducing dioxin and furan levels. Finally, the use of a high temperature afterburner when reactivating GAC that received unchlorinated water provides the ultimate level of protection available at the Cincinnati site.

Thus, the use of GAC before chlorination to remove man-made and naturally occurring organics from industrial source waters is the preferred mode of operation for several reasons. Alternate disinfection byproducts are greatly minimized because organic precursors are adsorbed by the GAC before exposure to chlorine. Both THM and TOX data support these conclusions. Certain specific organics are better adsorbed by GAC with reduced competition that results by preventing chlorinated organics from being formed during the disinfection process. Additionally, reactivation studies conducted at Cincinnati show that lower stack emissions of chlorinated organics, namely, chlorinated dibenzo-p-dioxins and chlorinated dibenzo furans, are produced by reactivating GAC that had received unchlorinated water.

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rated at one tenth the potency factor of 2,3,7,8-TCDD and the octa-CDD's are rated as no risk at all compared to 2,3,7,8-TCDD (14).

Tables 9 and 10 list results of two runs that included the analysis of tetra, penta, hexa, hepta and octa homologues of the CDD's and CDF's. Table 9 shows that no CDD's below hepta-CDD were present with the afterburner on. Operation without the afterburner showed that emissions of CDD's were very low. However, the high temperature afterburner did provide a better quality effluent. Table 10 lists CDF data that indicate the afterburner appears to have improved the quality of the reactivation effluent. All of the homologues of the CDF's were reduced in the emissions with the afterburner operating. Also less total CDF's were emitted than total CDD's when the afterburner was operating. This was not true for the test shown without the afterburner in operation.

Table 11 lists the results of the risk estimates performed by USEPA personnel at Research Triangle Park (15). Assessments were performed for the 585 lb/hour unit used in collecting the data described in this paper. Estimates were calculated from the data collected with and without the high temperature afterburner in operation. Tests 5 and 6 were chosen by USEPA for the risk assessments because they provided both worst case analyses and conditions that could be expected to be present during operation. Test 5 would be the representative of operations whereby the high temperature afterburner is in use with the air pollution control systems in place. Test 6 can be used to estimate the effects that might occur without the afterburner operating and without the air pollution control equipment in place. Projections of the risk estimates posed by a full scale GAC facility with on-site reactivation are also presented. The results shown on Table 11 prove that operating the afterburner further reduces risks that were already considered far below the level of credible risks. The authors would also point out that there are also many conservative estimates built into those risks estimating procedures. For instance, the human exposure model assumes a seventy year continuous exposure to the worst case concentrations detected. Also, the risk estimates have included the homologues of both the dioxins and furans, neither of which have been proven to be a human carcinogen. These are prudent assumptions that are intended to insure that any risks present the worst possible scenario. Thus if we meet with approval, under these conditions, then the practical likelihood of any risk to the public truly approaches zero. The worst case presented for the data collected during operation of the 585 lb/hr unit shows a 5×10^{-8} risk estimate. Thus, the worst risk that one living near the facility would have is a one in twenty million chance of developing cancer during their lifetime because of emissions from the reactivation system at our treatment plant. Operating the afterburner reduces the lifetime risk to one in twenty billion. These estimates are considerably less than those predicted for municipal solid waste incinerators tested for use in resource recovery applications in the United States (16).

Conclusions

Dioxins and furans have been discovered during reactivation of GAC. The health risks posed by the levels found have been shown to be insignificant. The performance of two sequential phases showed that chlorinating water before GAC treatment instead of after GAC treatment in-

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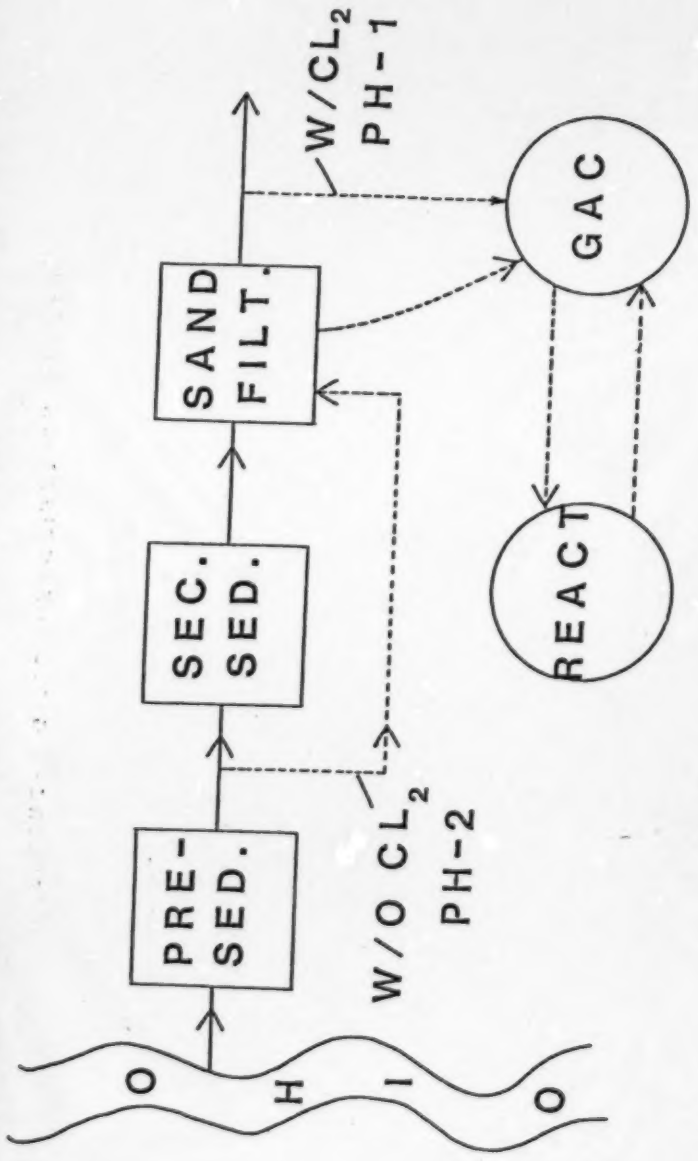

FIGURE-1 C.W.W. SCHEMATIC

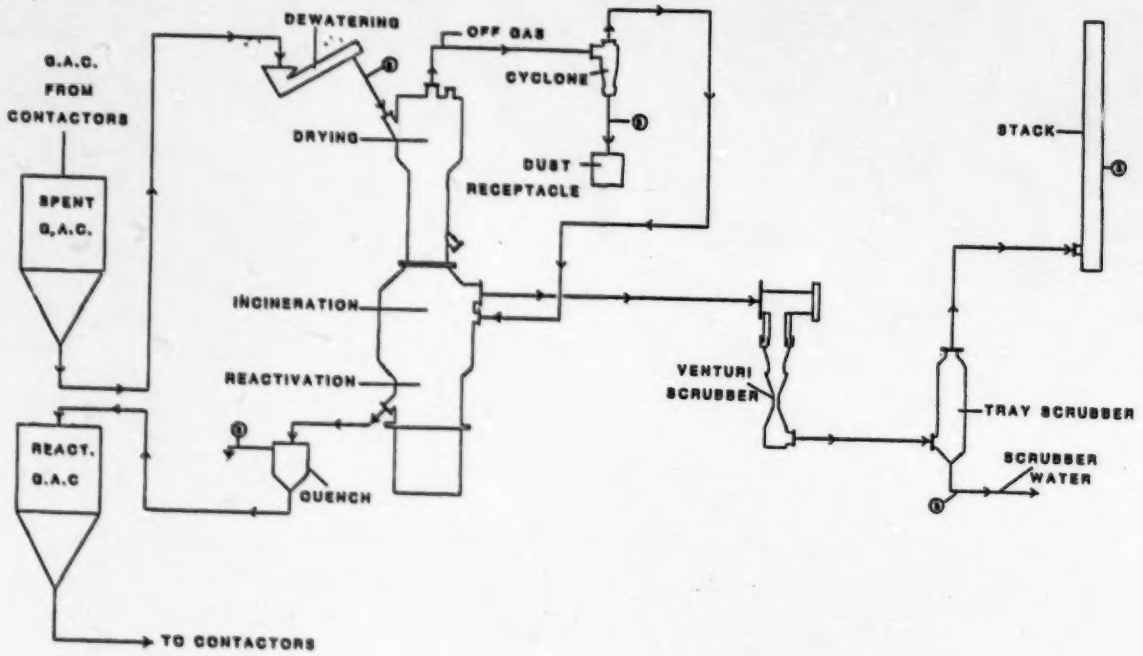

FIGURE-2 G.A.C. REACTIVATION SYSTEM

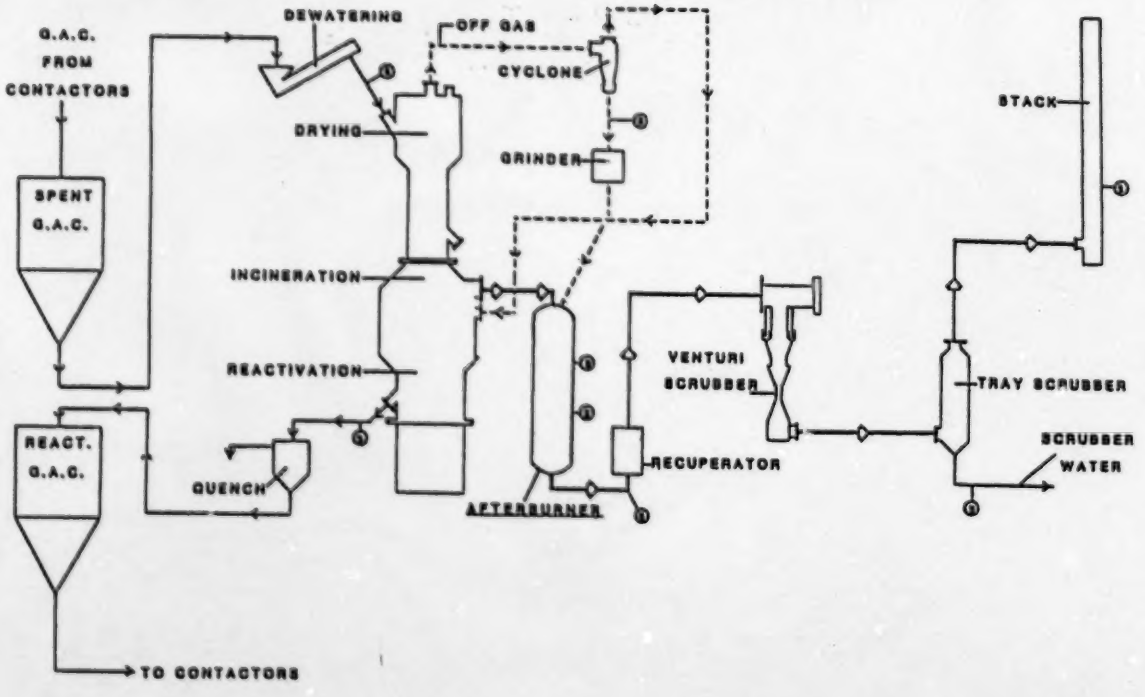

FIGURE-3 G.A.C. REACTIVATION SYSTEM WITH AFTERBURNER

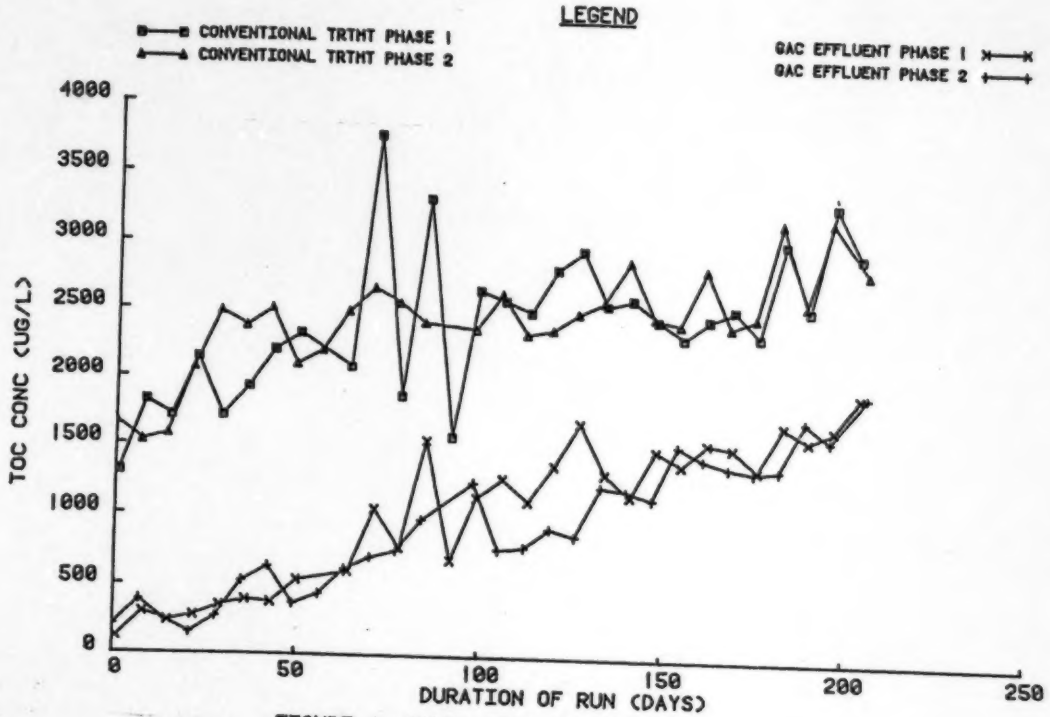

FIGURE 4. TOTAL ORGANIC CARBON
CONSUMERS TAP

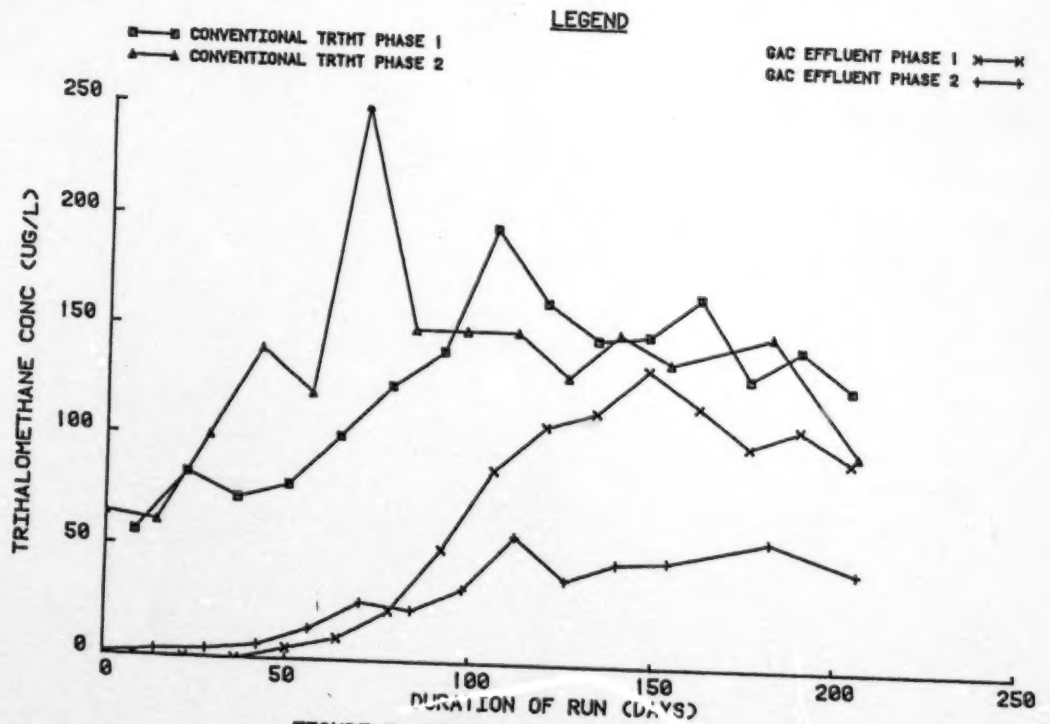

FIGURE 5. TRIHALOMETHANES
CONSUMERS TAP

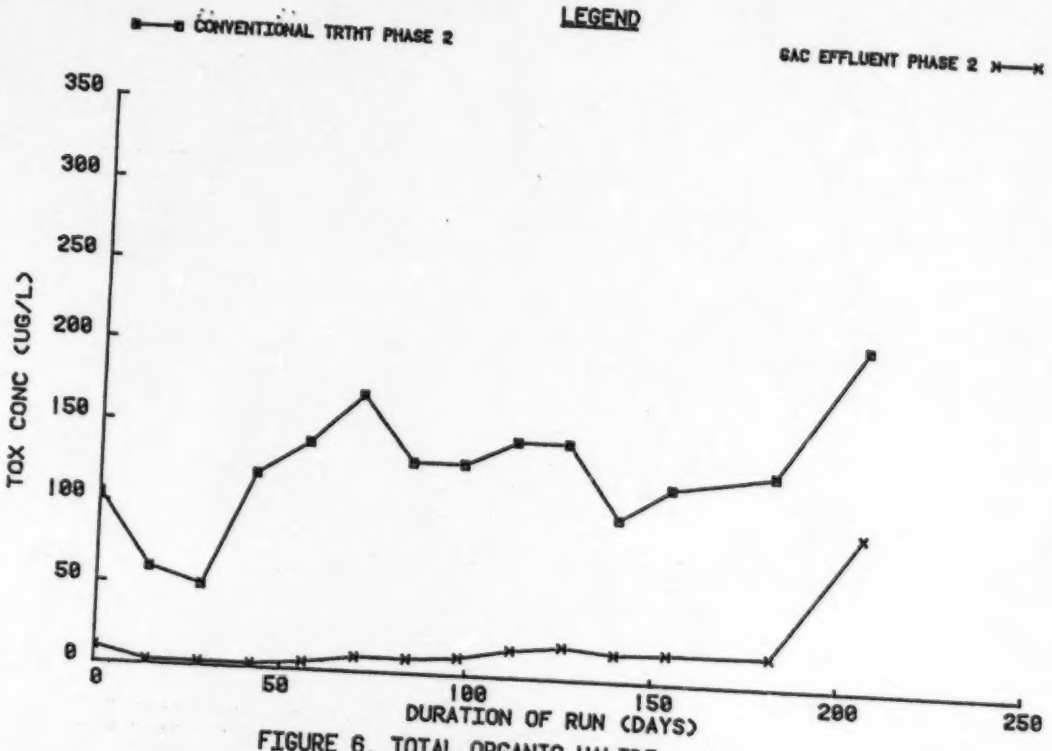

FIGURE 6. TOTAL ORGANIC HALIDE LEAVING PLANT

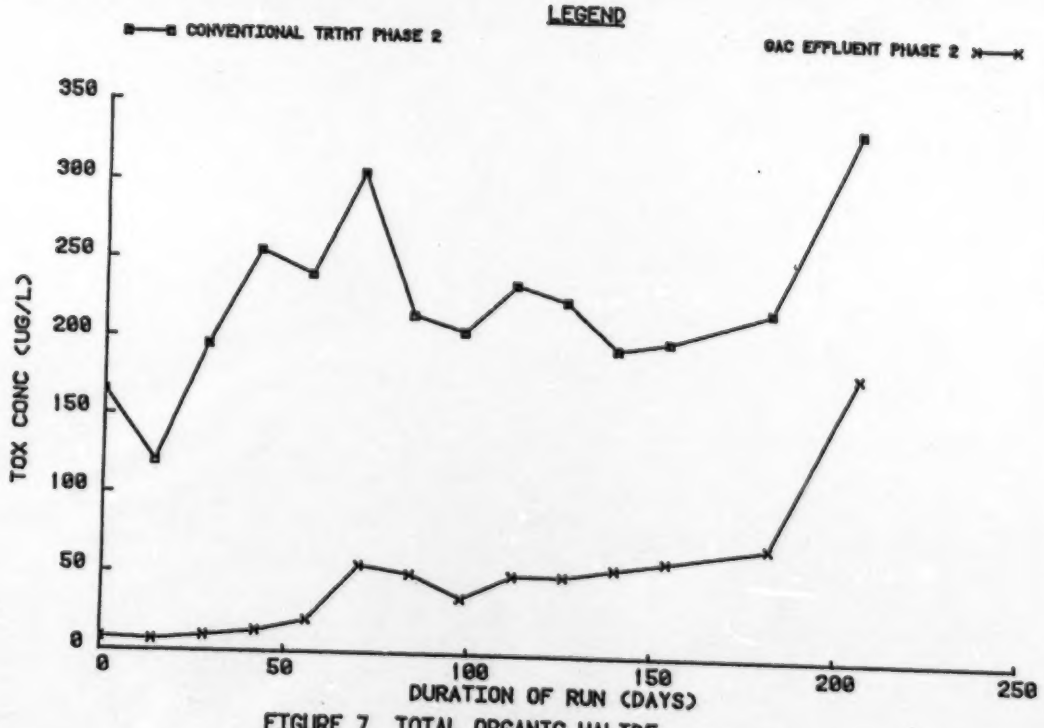

FIGURE 7. TOTAL ORGANIC HALIDE CONSUMERS TAP

TABLE 1

TYPICAL REACTIVATION TEST CONDITIONS

	Phase 1 GAC With Pre-Chlorine Average	Phase 2 GAC Without Pre-Chlorine Run 5	Phase 2 GAC Without Pre-Chlorine Run 6
Duration of Test Run (Hour)	4	4	4
Furnace Loading			
KG Carbon/hour	266	266	266
LB Carbon/hour	585	585	585
Fuel Used (BTU/LB GAC)			
Total	4488	6812	3820
Incineration	2136	1838	1923
Reactivation	1496	897	940
Steam	856	1197	957
Afterburner	-	2880	-
Steam Used (LB/LB GAC)	0.51	0.76	0.73
Temperatures (°F)			
Reactivation	1563	1566	1526
Incineration	1445	1736	1838
Afterburner	-	2453	-
Dryer	302	299	315
Scrubber	131	124	77

TABLE 2

SAMPLE LOCATIONS FOR DIOXIN AND FURAN TESTS

Description	GAC With Pre-Chlorine	GAC Without Pre-Chlorine
Spent GAC	X	X
Reactivated GAC	Not sampled	X
Cyclone Catch	X	X
Stack Emissions	X	X
High Temperature Afterburner Emissions	Not available	X
Scrubber Water	X	X
Quench Water	X	Not sampled

TABLE 3

CHLORINATION EFFECTS ON TOTAL TCDD'S

Sample	Phase 1 GAC With Pre-Chlorine Test Number 1	2	3	4	Phase 2 GAC Without Pre-Chlorine Test Number 2	6
Spent GAC (ppb)	ND	ND	ND	ND	ND	*
Reactivated GAC (ppb)	*	*	*	*	ND	*
Cyclone Catch (ppb)	3.3	0.2	4.1	1.3	ND	0.02
Stack Emissions (ppt)						
Particulates	0.2	0.2	0.05	0.1	ND	ND
Gaseous	ND	0.05	ND	ND	ND	0.003
TOTAL	0.2	0.25	0.05	0.1	ND	0.003
Scrubber Water (ppt)	ND	0.2	0.1	ND	ND	ND
Quench Water (ppt)	ND	ND	ND	ND	*	*

ND - Not Detected

* - Not Sampled

TABLE 4

CHLORINATION EFFECTS ON TOTAL TCDF'S

Sample	Phase 1 GAC With Pre-Chlorine Test Number 1	2	3	4	Phase 2 GAC Without Pre-Chlorine Test Number 2	6
Spent GAC (ppb)	ND	ND	ND	ND	0.04	*
Reactivated GAC (ppb)	ND	*	*	*	ND	*
Cyclone Catch (ppb)	*	*	*	*	ND	0.77
Stack Emissions (ppt)	0.48	3.33	2.14	0.78		
Particulates	0.3	ND	0.3	0.2	ND	ND
Gaseous	0.1	0.07	ND	ND	0.005	0.675
TOTAL	0.4	0.07	0.3	0.2	ND	0.675
Scrubber Water (ppt)	ND	ND	ND	ND	ND	ND
Quench Water (ppt)	ND	ND	ND	ND	*	*

ND - Not Detected

* - Not Sampled

TABLE 5

CHLORINE EFFECTS ON TOX ADSORBED
(mg Cl-/kg GAC)

	Phase 1 GAC With Pre-Chlorine	Phase 2 GAC Without Pre-Chlorine
Virgin	Not Detected	< 50
Spent	657	398
Reactivated	55	< 50

TABLE 6

TCDD/TCDF LEVELS IN AFTERBURNER/STACK EMISSIONS
(ng/dscm)

Test Condition	Test Location	TCDD 2,3,7,8-	TCDD Total	TCDF 2,3,7,8-	TCDF Total
Natural Gas (Test 1)	Recuperator	ND	ND	ND	0.14
Fuel Oil (Test 7)	Recuperator	ND	0.09	ND	0.10
GAC - Without Afterburner (Test 2)	Recuperator	ND	ND	ND	0.02
(Test 6)	Recuperator	ND	0.01	0.02	1.36
GAC - With Afterburner (Test 3)	AB-2 sec	ND	ND	0.02	0.17
	Stack	ND	ND	0.02	0.10
(Test 4)	AB-2 sec	ND	0.01	0.05	0.39
(Test 5)	AB-2 sec	ND	ND	0.02	0.10
	Stack	ND	ND	ND	ND

ND - Not Detected

TABLE 7

CDD LEVELS IN REACTIVATOR PROCESS SAMPLES

Sample	2,3,7,8-	Tetra-	Penta-	Hexa-	Hepta-	Octa-	Total
Spent GAC (ppb)	ND	ND	ND	ND	0.05	0.15	0.20
Reactivated GAC (ppb)	ND	ND	ND	ND	ND	0.28	0.28
Scrubber Water (ppt)	ND	ND	ND	ND	ND	0.22	0.22

ND - Not Detected.

All samples collected during operation of high temperature afterburner.

TABLE 8

CDF LEVELS IN REACTIVATOR PROCESS SAMPLES

Sample	2,3,7,8-	Tetra-	Penta-	Hexa-	Hepta-	Octa-	Total
Spent GAC (ppb)	ND	0.04	ND	ND	0.07	ND	0.11
Reactivated GAC (ppb)	ND	ND	ND	ND	ND	ND	ND
Scrubber Water (ppt)	ND	ND	ND	ND	ND	ND	ND

ND - Not Detected.

All samples collected during operation of high temperature afterburner.

TABLE 9

AFTERBURNER EFFECTS ON CDD EMISSIONS
GAC - WITHOUT PRE-CHLORINE (ng/dscm)

Test Condition	Test Location	Sample Fraction	Tetra-	Penta-	Hexa-	Hepta-	Octa-	Total
GAC With Afterburner (Test 5)	AB-2 sec	Particulate	ND	ND	ND	0.273	0.984	1.257
		Gaseous	ND	ND	ND	0.024	0.121	0.145
		Total	ND	ND	ND	0.297	1.105	1.402
	Stack	Particulate	ND	ND	ND	0.174	1.067	1.241
		Gaseous	ND	ND	ND	0.124	0.222	0.346
		Total	ND	ND	ND	0.298	1.289	1.587
GAC Without Afterburner (Test 6)	Recuperator	Particulate	ND	ND	ND	0.233	1.377	1.610
		Gaseous	0.006	0.128	0.372	0.233	0.233	0.972
		Total	0.006	0.128	0.372	0.466	1.610	2.582

ND - Not Detected

TABLE 10

AFTERBURNER EFFECTS ON CDF EMISSIONS
GAC - WITHOUT PRE-CHLORINE (ng/dscm)

Test Condition	Test Location	Sample Fraction	Tetra-	Penta-	Hexa-	Hepta-	Octa-	Total
GAC With Afterburner (Test 5)	AB-2 sec	Particulate	ND	0.015	0.035	0.073	0.048	0.171
		Gaseous	0.098	0.044	0.029	0.018	0.012	0.201
		Total	0.098	0.059	0.065	0.091	0.060	0.372
	Stack	Particulate	ND	ND	0.007	0.021	0.018	0.046
		Gaseous	ND	ND	ND	ND	ND	ND
		Total	ND	ND	0.007	0.021	0.018	0.046
GAC Without Afterburner (Test 6)	Recuperator	Particulate	ND	0.007	ND	ND	0.368	0.375
		Gaseous	1.357	1.067	0.756	0.756	0.349	4.285
		Total	1.357	1.074	0.756	0.756	0.717	4.660

ND - Not Detected

TABLE 11

EFFECT OF AFTERBURNER ON RISK ASSESSMENTS
(COMBINED CDD'S AND CDF'S)

Reactivator GAC Feed Rate lb/hr	RISK ESTIMATES* Without Afterburner	With Afterburner
585	5×10^{-8}	5×10^{-11}
2085	4×10^{-8}	6×10^{-11}

*Estimates represent expected maximum lifetime cancer risk to area residents.

MANGANESE REMOVAL USING POTASSIUM PERMANGANATE IN LOW pH, LOW HARDNESS WATERS

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INTRODUCTION

Manganese is the 12th most abundant element and th abundant metal in the earth's crust.(1) While manga exist free in nature, it is a major constituent in minerals and an accessory element in more tha minerals.(1) It should not be suprising therefore, is found in many raw drinking water sources.(2) In a re the AWWA Inorganic Contaminants Committee,(2) mangane as present in 1998 or 27.4% of the respondent's finishe estimated to be present in about 2000 other drinking problem is that these listings show manganese concentra of the secondary standards of the Safe Drinking Wa recommended concentration is 0.05 mg/L.(3) Th manganese in the finished water therefore is not unusua surface supplies.(4)(3) This paper addresses ti the most difficult-to-treat waters -- those with

- relatively low pH levels 6.5 - 7.0;
- alkalinities of < 20 mg/L;
- hardness levels of < 25 mg/L as $CaCO_3$.

After a short description of the problem, the paper approach taken in

- evaluating the conditions normally used these waters;
- determining the optimum coagulation pro
- establishing the best conditions for th potassium permanganate in the laborat

It will then present some actual field data obtained laboratory findings to solve a field problem.

DISCUSSION

As mentioned earlier in the paper, manganese is pres supplies. In concentrations exceeding the rec 0.05 mg/L, manganese will cause stains on launc fixtures. It will also cause "black water" complaint distribution system.

Manganese is an interesting element. It can exist states ranging from zero in manganese metal Mn^0, to the permanganate ion $Mn^{+7}O_4^-$.(5) The most comm soluble manganous ion, Mn^{+2}, which is the form mo water supplies, and the manganic ion, Mn^{+4}, which oxidized form. An understanding of the properties o can help when determining the optimum treatment manganese.